

FIG. 29 (shown dashed in FIG. 30) is formed using the background doping of EPI-2 layer 74, 740 of FIG. 20 and WELL 75 of FIG. 22 corresponds just to portion 52 of FIG. 30, that is, to WELL region 75-1 in FIG. 30. Persons of skill in the art will understand that the doping of EPI-2 region 74, 740 of FIG. 20 may be adjusted with this embodiment in mind so as to provide the desired values of Rbe.

[0061] In another embodiment, where it is desired that region 51 of FIG. 29 have a doping different than that of EPI-2 layer 74, 740 of FIG. 20, for example, intermediate between the doping of EPI-2 layer 74, 740 and that illustrated above for base portion 52 (75-1). To accomplish this, manufacturing stage 122 of FIG. 22 may be altered as illustrated by way of example in manufacturing stages 122-1 and 122-2 of FIGS. 22-1 and 22-2. FIGS. 22-1 and 22-2 are simplified cross-sectional views of an ESD clamp of the type illustrated in FIG. 9 showing variations of manufacturing stage 122 of FIG. 22, according to additional embodiments of the present invention and showing further detail. In a preferred embodiment, manufacturing stage 122 of FIG. 22 comprising Implant B is replaced by manufacturing stage 122-1 comprising Implant B1 and manufacturing stage 122-2 comprising Implant B2. In manufacturing stage 122-1 of FIG. 22-1, mask 91-1 is provided on SC surface 71, having closed portions 911-1 and openings 912-1 and 913-1, suitable for defining WELL regions 51i, 51i'. A suffix "i" is used here to indicate that initial base portions 51i, 51i' may differ in lateral extent from final base portions 51, 51' of FIG. 29. In a preferred embodiment, WELL region 51i, 51i' may have the same lateral dimensions as WELL region 75, 75' of FIG. 22, and depth 54 may be the same as depth 751 of FIG. 22, but larger or smaller lateral dimensions and depths may also be used. However, the doping desired for base WELL region 51i, 51i' resulting from Implant B1 of FIG. 22-1 is desirably smaller than that for WELL region 75 resulting from Implant B of FIG. 22. Region 51i, 51i' is desirably implanted to provide a doping density in the range of about $1\text{E}16$ to $1\text{E}18\text{ cm}^{-3}$ and preferably in the range of about $4\text{E}16$ to $8\text{E}16\text{ cm}^{-3}$, but higher and lower doping may also be used. Structure 222-1 results.

[0062] Referring now to manufacturing stage 122-2 of FIG. 22-2, mask 91-1 of manufacturing stage 122-1 is replaced with mask 91-2 having closed portions 911-2 and openings 912-2, 913-2. Implant B2 is provided through openings 912-2, 913-2, so as to form base portions 52, 52' having doping density usefully in the range of about $1\text{E}17$ to $1\text{E}18\text{ cm}^{-3}$, preferably in the range of about $4\text{E}17$ to $8\text{E}17\text{ cm}^{-3}$, but higher and lower doping may also be used. Structure 222-2 results. In a preferred embodiment, other than geometry, Implant B2 can be similar to Implant B of FIG. 22 for providing region 75. Accordingly, in FIGS. 29-30, portion 52 is also identified as region 75-1.

[0063] In manufacturing step 122-1 of FIG. 22-1, mask openings 912-1 and 913-1 providing base portions 51i, 51i' are shown as being wide enough to significantly overlap at least part of the location of mask openings 912-2 and 913-2 of manufacturing stage 122-2 of FIG. 22-2 providing base portions 52, 52'. While this is preferred since it simplifies alignment, it is not necessary and in still further embodiments, such overlap may be eliminated. In this configuration mask openings 912-1 and 913-1 of manufacturing stage 122-1 of FIG. 22-1 may be narrowed to eliminate some or all overlap with subsequently formed base portions 52, 52'. Then base portions 51i, 51i' correspond substantially to base portions 51,

51' substantially side-by-side with base portions 52, 52' rather than significantly overlapping base portions 52, 52'. Either arrangement is useful.

[0064] Having completed manufacturing stage 122-2, structure 222-2 is subjected to manufacturing stages 123-128 of FIGS. 23-28 keeping in mind the presence of base portions 51, 52, thereby yielding the structure illustrated in FIGS. 29 and 30 where base portion 51 has a different doping density (e.g., lighter), than the doping density of base portion 52. In a preferred embodiment, base portion 51 has doping density intermediate between the doping density of base portions 74, 85 formed from EPI-2 layer 74, 740 of FIG. 20 and the doping density of base portion 52. In this way, the resistance Rbe of transistor 56 is increased since the sheet resistance of base portion 51 is increased relative to base portion 52, thereby improving damage-onset threshold current It2. Because the doping density of base portion 52 is substantially unchanged, the improvement in It2 is achieved without significantly altering Vt1. Accordingly, a more robust ESD device having substantially the same threshold voltage Vt1 can be obtained in both single stage and multi-stage devices. This is very desirable. An advantage of modifying Rbe by changing the sheet resistance of base portion 51 is that no increase in ESD device area results. This is also desirable. While it is desirable to provide base portion 52 (e.g., of higher doping density) proximate boundary 752, in other embodiments such higher doping density base portion 52 may be omitted. In such cases, the doping density of WELL region 75 of FIGS. 4, 9, 17, etc., can be adjusted to provide the desired increase in Rbe and spacing D modified to achieve the desired Vt1 value in either single or multi-stack devices. Either arrangement is useful.

[0065] Persons of skill in the art will understand based on the teachings herein that Rbe (and therefore It2) can be increased by varying either the sheet resistance of base portion 51 (e.g., as illustrated in connection with FIGS. 29-30 and FIGS. 22-1, 22-2) or by increasing the sheet resistance of WELL portion 75 as a whole (e.g., as illustrated in FIGS. 4, 9, 17, etc.) or by varying Lbe (e.g., as discussed in connection with FIGS. 25, 29, 22-1 and 22-2) or by a combination of such arrangements. Thus, the embodiments of the present invention illustrated herein provide a high degree of flexibility in improving ESD damage-onset threshold current It2 to obtain more robust ESD devices. This flexibility is very useful for tailoring ESD devices to suit specific applications and is a particular advantage of the present invention.

[0066] According to a first embodiment, there is provided an electrostatic discharge (ESD) clamp having a predetermined threshold voltage Vt1, comprising, a bipolar transistor (56, 58) having a first surface (71) and underlying the first surface (71) having a base (51, 52, 74, 75, 85) of a first conductivity type, a base contact (77) of the first conductivity type extending into the base (51, 52, 74, 75, 85) from the first surface (71), an emitter (78) of a second, opposite, conductivity type extending into the base (51, 52, 74, 75, 85) from the first surface (71) and laterally separated from the base contact (77) at the first surface (71) by a distance Lbe, and a collector (86, 762) proximate the base (51, 52, 74, 75, 85), wherein the base (51, 52, 74, 75, 85) comprises a first base portion (51) containing the base contact (77) and the emitter (78) and having a first base dopant concentration, a second base portion (52) located laterally between the first portion (51) and a first boundary (752) and having a second base dopant concentration, and a third base portion (85) of width D located laterally between the boundary (752) and a portion (86) of the